GROWTH, CULL, AND MORTALITY AS FACTORS IN MANAGING TIMBER IN THE ANTHRACITE REGION

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INTRODUCTION

Timberland owners in the Anthracite Region of Pennsylvania frequently ask: What tree species grow best in the region? How large should they be grown? How should we treat them to get the most out of them?

There is no final, complete answer to these questions. But the data in this report may be useful as a guide in handling the 21 main species[1/] that grow in the Anthracite Region.

These data were gathered in a recent survey of the condition of the forests in the Anthracite Region, during which over 11,000 trees on 163 sample plots were studied. Future records of actual performance will serve to refine these first estimates.

This information will serve the needs of forest research workers who are interested in intensive studies of forest growth and yields. For the timberland owner and the practical forester, the findings have been condensed into averages that they can readily use to find the answers to questions like these: Should a tree be cut now? Is it worth while to wait 15 years before cutting in the hope of getting a greater volume of lumber? Or will the tree be full of rot by then? Which species should be favored?

In developing this information about the timber trees of the

[1/] 3 conifers--eastern hemlock, eastern white pine, pitch pine--and 18 hardwoods: red maple, sugar maple, white ash, basswood, American beech, trembling aspen, black cherry, yellow birch, black birch, white oak, chestnut oak, eastern red oak, northern red oak, scarlet oak, black oak, yellow poplar, pignut hickory, and mockernut hickory.

Anthracite Region, three of the most important silvicultural factors in managing forests were considered: growth, cull, and mortality. These factors are especially important when the selective method of timber harvesting is to be used. Their relation to tree development as it varies with species, site quality, and stand size must be thoroughly understood before forest-management practices can be prescribed.

GROWTH

DIAMETER GROWTH

No two species show exactly the same growth patterns (tables 5 and 6). The most intolerant trees--yellow poplar, black cherry, and red oak--have the highest growth rates, but they reach their peaks at an early age.

Average diameter growth increases as tree diameter increases, up to a culminating point; then the trend reverses. These peaks of average growth indicate the sizes at which tree vigor starts to diminish with age. Average volume growth, however, continues to rise for a short time after diameter growth begins to slow down.

The points where growth culminates vary considerably among species, depending upon the individual characteristics that control longevity. Red oak, for example, grows rapidly in the younger stages, but culminates at an early age. White oak, on the other hand, shows no culmination point within the limits of our data. This confirms the findings of Sterrett.2/

The growth of an individual tree is influenced directly by the stand-size class of the forest in which it grows. When trees are crowded together they must compete with each other, and growth is slowed. This effect can be seen readily by comparing trees of the same size in the different stand-size classes. For example, a 5-inch tree in a seedling-and-sapling stand will grow faster than a 5-inch tree in a pole-timber stand; and both will grow faster than a 5-inch tree in a saw-timber stand.3/ In young forests, stems having diameters 4, 5, or

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2/ Sterrett, W. D. The oaks of eastern United States: their distribution and commercial importance. 1921. (Unpublished ms., 86 pp. Northeast. Forest Expt. Sta., Anthracite Area Branch, Kingston, Pa.)

3/ The standards used are as follows: A saw-timber stand has a minimum of 2,000 board feet per acre, of conifers 9 inches d.b.h. and larger, and of hardwoods 11 inches d.b.h. and larger. A pole-timber stand has a minimum of 5 cords per acre, of trees 4 inches d.b.h. and larger, but less than 2,000 board feet in saw-timber sized trees. A seedling-and-sapling stand has less than 5 cords per acre of trees 4 inches d.b.h. and larger.

6 inches have dominant positions, with ample room for developing their crowns. In older stands trees of this size become crowded; often they are overtopped and suppressed. In figure 1 the annual ring patterns show how the stand size affects growth.

The site also has a direct effect on tree growth. In general, diameter growth of all species is higher on site I than on site II, and the culmination points are in higher diameters.

Site I conditions are found in moist, well drained coves or on lower slopes; here dominant and co-dominant hardwoods produce 3 or more 16-foot logs (conifers $3\frac{1}{2}$ or more) in mature stands. Site II conditions are found on slopes between ridges and coves, or in poorly drained bottom-lands, where dominant and co-dominant hardwoods produce 2 to $2\frac{1}{2}$ 16-foot logs (conifers $2\frac{1}{2}$ to 3) in mature stands.

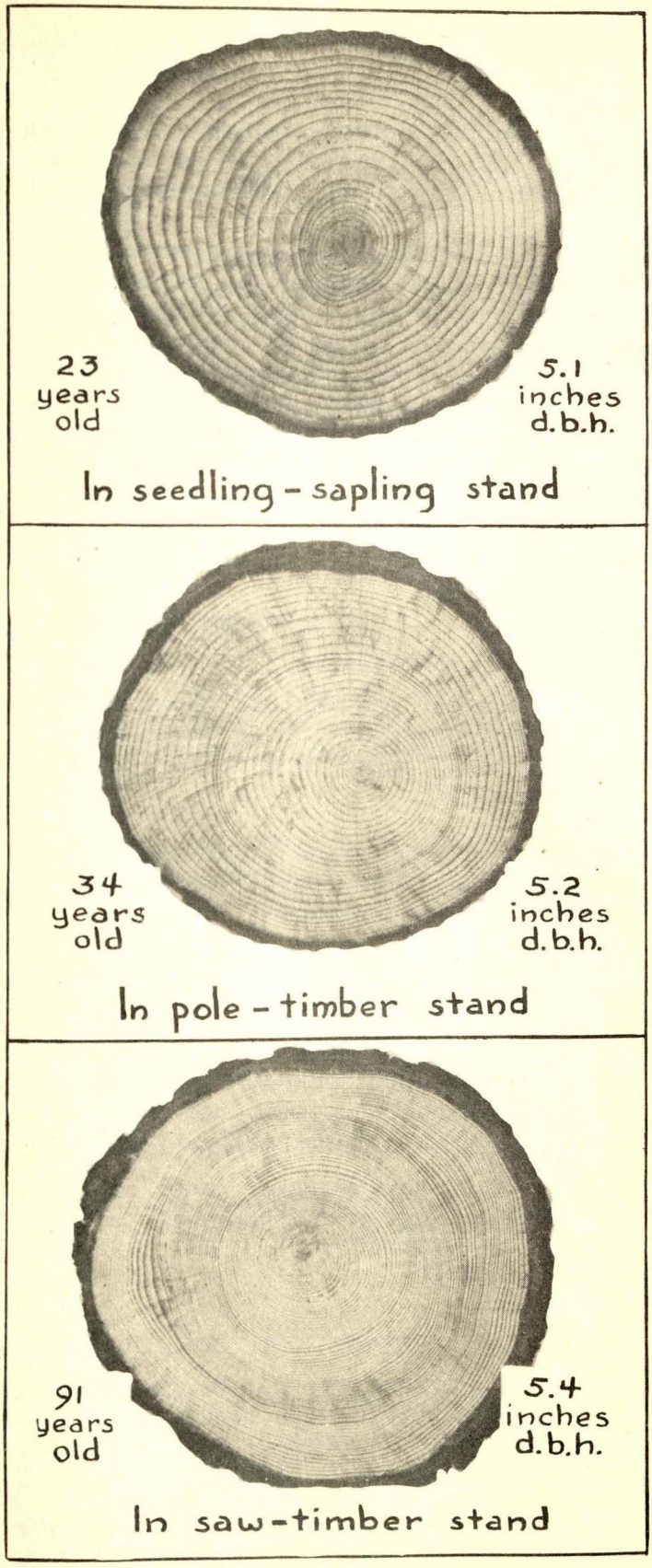

Figure 1.--Annual rings in these cross sections from three trees show how stand size affects growth.

VOLUME GROWTH

Volume growth (tables 7 and 8) was computed from diameter growth rates (tables 5 and 6). These were converted to cubic-foot volume increment by applying appropriate volume tables.4/

Naturally these data reflect the trends shown by diameter growth. The chief difference is the diameter at which growth for the various species culminates. The greatest rate of diameter growth for nearly all species was found in trees less than 24 inches in diameter. When expressed in terms of cubic-foot volume, these peaks are naturally somewhat higher, as large trees require less diameter growth to produce an equal amount of cubic volume. Because of the immense importance of quality increment, species of high value--black cherry, white ash, white pine, sugar maple, and yellow poplar--can be profitably held for 10 to 20 years beyond volume growth culmination, unless they show evidence of decay.

TREE VIGOR AND GROWTH

How can the fastest growing trees be identified? The size and density of the functioning crown is so closely correlated with growth that it can be used as a criterion in classifying trees into broad vigor classes.

The vigor classifications used here are similar to those used by Hough and Taylor5/ for Allegheny northern hardwoods. Four vigor classes are recognized:

1. Trees usually dominant or co-dominant, having large dense crowns usually half exposed, and a healthy and thrifty appearance; no stag heads or dead limbs, no sign of disease.
2. Trees often co-dominant, having less dense crowns, less than half exposed; free from disease or mechanical breakage; no old-age stagnation.
3. Trees having small dense crowns, tips barely exposed. Generally poorer than class 2.

4/ Burnham, C. F., Ferree, M. J., and Cunningham, F. E. Site class volume tables for merchantable timber in the Anthracite Region of Pennsylvania. Northeast. Forest Expt. Sta. Forest Management Paper 3. 16 pp. (processed). 1946.

5/ Hough, A. F., and Taylor, R. F. Response of Allegheny northern hardwoods to partial cutting. Jour. Forestry 44: 30-38. 1946.

4. Trees under obvious handicaps such as severe suppression; may be injured, diseased, or stagnated.

A tree's growth rate depends primarily on its vigor (table 9). As vigor decreases there is a constant and significant drop in growth rate.

Within the four vigor classes, the growth rate varies with species and site quality. To show how vigor affects growth, species that have similar growth rates in each vigor class have been grouped together (table 9). These groupings are different for each forest site. For example, vigor 1 yellow poplar heads the list for growth on site I; but on site II black cherry does best, and yellow poplar comes third.

CULL[6/]

For most species the proportion of cull increases with tree size (tables 10 and 11). This relationship, however, is not strictly one between diameter and cull. Since large trees are usually older and have been subjected to a greater number of fires and other injuries, age also has a bearing on the amount of cull.

Aspen, white ash, and black cherry are exceptions to the general trend. In the lower diameter classes these species show a decrease in cull percentages as tree size increases. In the higher diameters the reverse occurs and they assume trends similar to those of the other species. The mortality rates (tables 12 and 13) explain this behavior. The smallest sized trees of these species, because of their intolerance to shade, show high rates of natural dying. Evidently the trees that succumb are defective. The few surviving ones attain dominant positions in the stands and show little decay until natural crowding again occurs when the stems become older. From this point on there is a normal increase in cull percentages with increase in size.

The proportions of defect vary considerably by groups of species. These differences may be due to differences in susceptibility to decay,

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6/ Cull was estimated according to methods outlined by Spaulding, Hepting, and Westveld (Revised suggestions for estimating cull in northern hardwoods; Northeast. Forest Expt. Sta. Tech. Note 14, 3 pp., 1934) and by W. M. Zillgitt (A quick method of estimating cull in northern hardwood stands; Lake States Forest Expt. Sta. Tech. Note 225, 1 p., 1946).

or by certain species' having experienced similar mechanical injuries or damage from forest fires. Black and yellow birch, American beech, red maple, and trembling aspen are very susceptible to decay, and contain high proportions of defective volume, regardless of where they occur.

Trees of the same size have a higher percentage of defective material in saw-timber stands than in younger stands, largely because of greater age and decreased vigor.

In general, trees on site II show a higher percentage of defect than those on site I. Again the difference is attributed to the effect of age. On the better sites trees grow faster; therefore individuals of the same size are younger on the good site than those on the poorer sites. The difference is more pronounced for some species than for others.

MORTALITY

Mortality rates are high for small trees; they drop as the stems increase in size (tables 12 and 13). This trend holds true--to the limits of the collected data--for all species except aspen. This species shows an increase in mortality after reaching the 9- and 6-inch sizes on sites I and II respectively. At these sizes the rates of natural dying increase, since aspen is a relatively short-lived species. It falls victim to competition and to attacks by diseases and insects at an early age. Similar reverse trends in the mortality rates hold true for all species, but as most of them are longer-lived the turning point is at diameters well above the 12-inch d.b.h. class.

Death rates vary greatly by species. Trees that are able to survive in dense shade, such as beech, sugar maple, and hemlock, show the lowest mortality rates.

Mortality rates for a given species may vary considerably by forest site and stand-size classes. The influence of both these factors is related to the ability of different tree species to endure shade. The intolerant species--yellow poplar, black cherry, and aspen--experience less mortality when growing on site II than on site I. For the shade-tolerant trees the reverse is true. This behavior reflects the severe competition the intolerant species encounter on the better sites with densely stocked stands, and the hardships they undergo in their struggle for establishment. For example, the effect of hardwood competition on white pine establishment is illustrated by the high mortality of white pine in the site I seedling-and-sapling stand. The intolerant species show an increase in mortality rates as stands progress from the seedling-and-sapling stage to the saw-timber stage. Tolerant species, being less sensitive to competition, show an opposite trend.

PRACTICAL APPLICATION

The forest research worker who is interested in intensive studies of forest growth and yields will find tabular data on growth, cull, and mortality at the end of this report.

For timberland owners and practical foresters the significant findings of the study have been boiled down into averages that they can apply to practical problems of forest management and harvest cutting. These average figures will not necessarily give accurate results for individual trees, but for groups of trees they should be reasonably close to the true values.

For each species, these average figures provide a guide as to when tree growth reaches its peak (table 1). They also tell the diameter at which cull generally exceeds 10 percent of the cubic-foot volume (table 2).

These can be useful in answering another important question: At what size should trees of a certain species be cut? (table 3). These sizes are the sizes that will yield the best cash return. It will pay to let trees grow to these sizes.

Table 1.--When average tree growth reaches its peak[1/]

Species	D.b.h. at which average 10-year growth in cubic feet starts to decline	
	Site I	Site II
	Inches	Inches
Eastern white pine	24+	22
Eastern hemlock	24+	14
Red oak	18	18
White oak	24+	24+
Sugar maple	24	18
Red maple	16	16
Hickory	18	12
American beech	16	16
Yellow birch	14	(2/)
Black birch	16	14
Yellow poplar	18	--
White ash	18+	18+
Black cherry	16	14+
Basswood	22	18+
Trembling aspen	10	8
Black oak	--	16
Chestnut oak	--	20

1/ Although some species show no decline in volume growth (tables 7 and 8), development of cull indicates these diameters to be approximately correct.

2/ Poor risk on site II.

Table 2.--Size at which cull exceeds 10 percent of volume

Species	D.b.h. at which cull exceeds 10 percent of total cubic-foot volume	
	Site I	Site II
	Inches	Inches
Eastern white pine	21	18
Eastern hemlock	21	14
Red oak	19	18
White oak	19	19
Sugar maple	18	14
Red maple	9	9
Hickory	19	13
American beech	9	9
Yellow birch	16	--
Black birch	9	5
Yellow poplar	21	--
White ash	19	18
Black cherry	21	20
Basswood	19	10
Trembling aspen	14	12
Black oak	--	19
Chestnut oak	--	12

But if they are not harvested when they attain these sizes, disease and injury and other cull factors will begin to reduce their value seriously. It is like harvesting a fruit crop such as apples: you wait until they are ripe before you harvest them, but if you wait too long they will begin to go bad.

The relative stumpage values of the species, based on recent prices, are a guide not only for harvesting timber for sale, but also for deciding which trees will be the real cash crop of the future and should be favored over the others in the management of the woodland.

In general, species that are highly susceptible to cull or culminate in growth rate at an early age should be harvested while they are quite small. If they have no special market value, they should be discriminated against in favor of species of higher value. This emphasizes the importance of improvement cuttings that would not only salvage much decaying timber, but would also serve as thinnings to increase growth rates on the remaining trees. The mortality data (tables 12 and 13) may be helpful in determining which species suffer greatest losses from competition and require release for best survival. Young white pine, for example, must be kept free from hardwood competition for best growth.

All desirable species that are quite resistant to decay and are not removed in a thinning operation should be held at least until they reach the peak of their growing capacities. Financially it pays. For

example, red oak is at present being cut for sawlogs when it reaches about 12 inches d.b.h., or approximately 65 years old in an unmanaged stand on site I. Such a tree contains a volume of 70 board feet (1/4-inch international scale). At an assumed stumpage value of $10 per thousand board feet, it is worth 70 cents. At 95 years, the age at which it should be cut, the tree will be 20.5 inches in diameter and will contain 385 board feet of lumber worth $3.85. Thus, by holding 12-inch red oak trees for 30 years their value can be increased more than five-fold.

Table 3.--When trees should be cut

Species	Relative stumpage value	Approximate d.b.h. at which trees should be cut to get best returns	
		Site I	Site II
		Inches	Inches
Eastern white pine	High	26	22
Eastern hemlock	Low	22	14
Red oak	Moderate	20	18
White oak	High	24	20
Sugar maple	High	22	18
Red maple	Low	14	12
Hickory	Moderate	20	14
American beech	Low	14	12
Yellow birch	High	18	--
Black birch	Moderate	14	12
Yellow poplar	High	24	--
White ash	High	22	18
Black cherry	Very high	20	18
Basswood	High	22	16
Trembling aspen	Low	12	10
Black oak	Moderate	--	18
Chestnut oak	Moderate	--	16

The above comparison does not make allowance for the increase in stumpage price that accompanies increase in size of most stems. For hardwoods under 16 inches it is estimated that over half of their total lumber yield is in No. 2 or No. 3 Common boards. Larger trees yield a greater proportion of high-grade lumber.

For forest management purposes, growth rates determined for trees growing in a natural condition made it possible to estimate the number

of years required to grow each species to its maturity size in unmanaged stands (table 4). In this calculation 5 to 10 years were added to allow for the time required to reach breast height. Vigor-

Table 4.--How management affects growth

Species	Years to grow to cutting size			
	Site I		Site II	
	In unmanaged stands	In managed stands	In unmanaged stands	In managed stands
Eastern white pine	135	110	130	115
Eastern hemlock	120	100	80	70
Red oak	95	85	115	100
White oak	145	110	155	125
Sugar maple	125	105	135	105
Red maple	90	70	95	65
Hickory	125	115	150	120
American beech	110	85	105	80
Yellow birch	115	100	--	--
Black birch	85	75	80	65
Yellow poplar	95	90	--	--
White ash	130	105	130	100
Black cherry	100	90	115	85
Basswood	120	110	115	75
Trembling aspen	60	55	60	55
Black oak	--	--	115	100
Chestnut oak	--	--	110	85

class growth rates made it possible to approximate the length of time required to grow it to maturity under management. It was assumed that trees treated properly could be kept growing at a vigor 2 rate.

TABULAR DATA

Detailed data developed in this study of growth, cull, and mortality are presented in the tables that follow. These data are for both site I and site II conditions. They include the following:

Ten-year diameter growth of trees in natural stands.

Volume increment for the last 10 years, in cubic feet.

Average 10-year diameter growth rates.

Cull factors for trees growing in natural stands.

Ten-year mortality.

The average maturity sizes and ages presented in table 14 are a composite of the data already presented in tables 1, 2, 3, and 4.

Table 5.--Ten-year diameter growth of trees in natural stands, site I

(In inches, measured at breast height)

Diameter of tree 1/ (inches)	Eastern white pine	Eastern hemlock	Red oak	White oak	Sugar maple	Red maple	Hickory	American beech	Yellow birch	Black birch	Yellow poplar	White ash	Black cherry	Trembling aspen	Basswood
IN SAW-TIMBER STANDS															
4	0.7	0.7	0.9	0.7	0.7	0.6	0.2	0.5	0.5	0.9	1.6	0.5	0.6	--	0.9
6	.9	1.0	1.0	.8	.9	.9	.6	.7	.7	1.0	2.2	.8	.7	--	1.0
8	1.0	1.2	1.3	.9	1.2	1.1	1.2	.9	.9	1.2	2.5	1.1	.9	--	1.1
10	1.1	1.4	1.7	1.0	1.5	1.2	1.6	1.1	1.0	1.3	2.8	1.4	1.2	--	1.4
12	1.3	1.6	2.2	1.1	1.7	1.3	1.7	1.2	1.0	1.4	2.9	1.7	1.7	--	1.6
14	1.4	1.8	2.8	1.2	1.9	1.4	1.6	1.3	.9	1.5	3.0	1.8	2.4	--	1.8
16	1.5	1.9	3.1	1.3	2.0	1.4	1.5	1.3	.9	1.4	3.0	1.8	2.2	--	1.9
18	1.6	1.9	2.9	1.3	2.1	1.3	--	1.2	--	--	2.8	1.7	1.0	--	2.0
20	1.8	1.9	2.3	1.3	2.2	--	--	1.0	--	--	2.4	--	.7	--	2.0
22	1.9	1.9	1.5	1.4	2.2	--	--	--	--	--	2.0	--	.6	--	1.9
24	2.0	1.8	1.0	1.4	2.1	--	--	--	--	--	--	--	--	--	1.8
IN POLE-TIMBER STANDS															
4	1.6	0.8	0.9	0.7	0.7	0.9	0.6	0.7	0.7	0.9	(2/)	0.7	1.2	1.3	0.9
6	1.8	1.0	1.1	1.1	1.3	1.1	1.0	.8	.8	1.1	(2/)	1.2	1.4	1.5	1.1
8	2.0	1.2	1.5	1.4	1.9	1.4	1.5	.9	.9	1.2	(2/)	1.6	1.6	1.7	1.6
10	2.2	1.5	2.2	1.6	2.5	1.6	1.9	1.0	1.0	1.3	(2/)	1.8	1.9	1.8	2.0
IN SEEDLING-AND-SAPLING STANDS															
4	1.9	1.8	1.8	1.3	1.2	1.3	1.7	1.2	1.9	2.0	1.9	1.3	1.8	1.8	1.3
6	2.5	2.0	2.5	1.8	1.4	1.5	2.0	1.3	1.9	2.1	2.2	1.6	2.1	1.8	1.7
8	3.1	2.1	3.1	2.0	1.6	1.6	2.2	1.4	2.0	2.2	2.5	2.0	2.3	1.8	2.0

1/ Measured at breast height ($4\frac{1}{2}$ feet above the ground), outside bark.
2/ Insufficient data.

Table 6.--Ten-year diameter growth of trees in natural stands, site II

(In inches, measured at breast height)

Diameter of tree[1] (inches)	Eastern white pine	Eastern hemlock	Red oak	White oak	Black oak	Chestnut oak	Sugar maple	Red maple	Hickory	American beech	Yellow birch	Black birch	White ash	Black cherry	Trembling aspen	Basswood
IN SAW-TIMBER STANDS																
4	0.7	0.6	0.9	0.4	0.8	0.6	0.7	0.6	0.2	0.5	0.5	0.8	0.5	0.6	--	0.7
6	.8	.9	1.0	.7	1.1	.7	.9	.8	.5	.7	.7	1.0	.8	.7	--	.9
8	.9	1.2	1.2	.8	1.4	.8	1.1	.9	.7	.9	.8	1.1	1.1	.9	--	1.1
10	1.1	1.4	1.4	1.0	1.6	.8	1.3	1.0	.7	1.1	.8	1.2	1.4	1.1	--	1.4
12	1.2	1.4	1.7	1.1	1.8	.9	1.4	1.1	.7	1.2	.7	1.2	1.7	1.4	--	1.5
14	1.4	1.4	1.8	1.1	1.7	.9	1.5	1.1	.6	1.2	.6	1.1	1.8	1.6	--	1.5
16	1.5	1.3	1.8	1.2	1.5	.9	1.6	1.1	--	1.1	--	1.0	1.8	--	--	1.5
18	1.6	--	1.6	1.2	1.0	.9	1.6	.9	--	1.0	--	--	1.6	--	--	1.4
20	1.5	--	1.4	1.3	--	.8	1.4	--	--	.6	--	--	--	--	--	--
22	1.4	--	1.1	1.3	--	.8	1.1	--	--	--	--	--	--	--	--	--
24	1.3	--	.9	1.3	--	.7	--	--	--	--	--	--	--	--	--	--
IN POLE-TIMBER STANDS																
4	0.7	0.8	0.8	0.7	0.9	0.7	0.7	0.9	0.5	0.7	0.7	0.8	0.6	1.2	1.3	0.7
6	.9	1.0	.9	1.1	1.0	.8	1.0	1.1	.7	.8	.8	1.0	.8	1.4	1.5	.9
8	1.3	1.1	1.1	1.3	1.1	1.0	1.1	1.3	1.0	.9	.9	1.2	1.0	1.6	1.6	1.1
10	1.7	1.3	1.4	1.4	1.2	1.1	1.2	1.3	1.2	1.0	.9	1.2	1.1	1.6	1.4	1.4
IN SEEDLING-AND-SAPLING STANDS																
4	1.9	1.8	1.4	1.3	1.2	1.1	1.0	1.2	(2/)	1.1	1.2	1.2	1.0	1.3	1.5	1.1
6	2.5	1.9	1.6	1.5	1.4	1.7	1.2	1.4	(2/)	1.2	1.4	1.2	1.2	1.4	1.6	1.3
8	3.0	2.0	1.8	1.6	1.6	2.3	1.4	1.7	(2/)	1.4	1.5	1.2	1.4	1.6	1.8	1.5

1/ Measured at breast height (4½ feet above the ground), outside bark.
2/ Insufficient data.

Table 7.--Volume increment for the last 10 years, in cubic feet, site I

D.b.h. o.b. (inches)	Eastern white pine	Eastern hemlock	Red oak	White oak	Sugar maple	Red maple	Hickory	American beech	Yellow birch	Black birch	Yellow poplar	White ash	Black cherry	Trembling aspen	Basswood
SAW-TIMBER STANDS															
4	0.4	0.2	0.6	0.4	0.7	0.6	0.2	0.2	0.3	0.8	2.0	0.2	0.2	1.3	0.4
6	1.6	1.3	1.8	1.2	1.8	1.6	1.3	1.1	1.2	1.8	5.2	1.7	1.2	3.6	1.8
8	2.9	3.3	3.4	2.3	3.2	2.6	3.0	2.3	2.4	2.8	9.0	3.3	2.6	5.0	3.5
10	4.4	5.3	6.2	3.4	4.8	3.9	5.2	3.9	3.2	4.1	13.2	5.4	4.8	5.6	5.4
12	6.2	7.6	10.5	4.9	7.0	5.5	7.8	6.0	3.8	5.5	17.5	8.0	8.8	5.6	7.6
14	8.2	10.2	15.9	6.6	9.6	7.6	9.4	7.5	4.2	6.5	21.2	11.1	13.4	--	10.0
16	10.6	12.8	22.0	8.5	12.2	8.4	10.0	8.0	4.2	6.9	23.8	12.6	13.9	--	11.8
18	13.4	15.4	23.5	10.2	14.2	8.3	10.1	7.8	--	--	25.0	13.0	9.2	--	13.0
20	16.8	17.6	20.0	11.7	15.4	--	--	7.0	--	--	24.6	--	5.6	--	13.6
22	20.7	19.2	15.7	12.6	15.8	--	--	--	--	--	23.3	--	4.6	--	13.6
24	25.5	19.8	12.2	12.8	15.8	--	--	--	--	--	--	--	--	--	13.3
POLE-TIMBER STANDS															
4	2.0	0.3	0.6	0.4	0.7	0.8	0.2	0.4	0.5	0.8	(1/)	0.3	0.8	1.2	0.5
6	3.8	1.2	2.2	2.1	2.8	2.1	1.9	1.2	1.4	2.0	(1/)	2.4	3.0	3.4	2.4
8	6.5	3.2	3.9	3.9	5.2	3.3	4.2	2.2	2.3	3.1	(1/)	5.1	5.4	5.0	5.1
10	9.0	6.5	8.0	5.6	8.5	4.8	6.7	4.1	3.0	4.0	(1/)	7.2	7.9	5.7	7.4
SEEDLING-AND-SAPLING STANDS															
4	2.5	1.4	1.6	1.3	1.2	1.4	2.0	1.1	2.2	2.4	2.6	1.1	2.0	2.2	1.3
6	5.7	3.2	5.5	3.5	3.0	2.9	3.9	2.0	3.8	4.3	5.4	3.3	4.8	4.1	4.0
8	10.9	6.0	9.3	6.0	5.3	3.9	6.7	3.7	5.4	6.0	9.5	6.6	6.9	5.2	6.5

1/ Insufficient data.

Table 8.--Volume increment for the last 10 years, in cubic feet, site II

SAW-TIMBER STANDS

D.b.h. o.b. (inches)	Eastern white pine	Eastern hemlock	Red oak	White oak	Black oak	Chestnut oak	Sugar maple	Red maple	Hickory	American beech	Yellow birch	Black birch	White ash	Black cherry	Trembling aspen	Basswood
4	0.2	0.1	0.4	0.1	0.5	0.3	0.5	0.5	0.2	0.2	0.2	0.5	0.2	0.2	0.1	0.3
6	1.1	1.3	1.4	.8	1.9	.8	1.2	1.1	.9	1.0	1.0	1.7	1.6	1.2	3.5	1.7
8	2.3	3.1	1.9	1.5	3.5	1.0	2.0	1.9	1.3	2.1	2.0	2.7	3.2	2.5	4.7	3.0
10	3.8	5.2	4.2	2.5	5.4	1.7	3.0	2.7	2.0	3.4	2.8	3.9	5.1	4.5	4.5	4.6
12	5.3	6.3	6.3	3.8	6.9	2.3	4.2	3.9	2.6	5.1	2.6	4.2	7.5	6.9	3.7	6.1
14	7.3	6.8	8.7	5.2	7.6	3.1	6.0	4.7	2.5	6.1	2.5	4.2	9.0	7.8	--	7.2
16	9.5	6.5	10.2	6.8	7.5	4.9	8.0	4.7	--	6.1	--	4.1	9.3	--	--	7.9
18	11.5	--	11.0	8.1	6.3	6.3	8.6	4.2	--	5.9	--	--	9.3	--	--	8.0
20	13.0	--	10.8	9.2	--	7.1	8.2	--	--	5.2	--	--	--	--	--	--
22	13.0	--	10.2	10.1	--	6.5	7.7	--	--	--	--	--	--	--	--	--
24	12.0	--	9.8	11.0	--	4.4	--	--	--	--	--	--	--	--	--	--
POLE-TIMBER STANDS																
4	0.2	0.1	0.3	0.1	0.4	0.1	0.4	0.5	0.1	0.1	0.3	0.5	0.1	0.7	1.0	0.2
6	1.7	1.5	1.8	2.1	2.0	1.5	1.9	1.9	1.3	1.4	1.3	1.5	1.6	2.6	3.5	1.8
8	4.0	3.1	2.7	3.0	2.7	2.2	2.3	2.4	2.3	1.8	1.9	2.7	2.9	4.6	4.5	3.2
10	6.7	5.0	4.3	3.9	3.6	3.0	2.8	3.1	3.3	3.1	3.0	4.0	3.9	5.9	4.5	5.0
SEEDLING-AND-SAPLING STANDS																
4	1.3	0.8	1.1	1.1	0.8	0.7	0.7	1.0	(1/)	0.6	0.9	0.9	0.5	0.8	1.4	0.7
6	5.6	3.4	3.3	2.9	2.8	2.4	2.3	2.4	(1/)	2.2	2.1	1.8	2.4	2.6	3.8	2.7
8	10.1	6.2	4.5	3.8	4.0	5.5	3.0	3.3	(1/)	3.2	3.6	2.8	4.1	4.6	4.5	4.5

1/ Insufficient data.

Table 9.--Average 10-year diameter growth rates[1/]

(Measured at breast height, outside bark)

Species group	Growth rate, in vigor class--			
	I	II	III	IV
	Inches	Inches	Inches	Inches
SITE I				
Yellow poplar	3.5	2.4	1.5	0.9
Black cherry, White ash, Eastern white pine, Red oak, American elm, Black oak	3.1	2.1	1.3	0.7
Eastern hemlock, Trembling aspen, Basswood, Scarlet oak, White oak, Sugar maple, Red maple, Pitch pine	2.7	1.9	1.2	0.6
Black birch, American beech, Yellow birch, Chestnut oak, Hickory	2.4	1.6	1.0	0.5
SITE II				
Black cherry, Basswood	2.8	2.0	1.3	0.7
Yellow poplar, Eastern hemlock, Eastern white pine, American elm, Trembling aspen, White ash, Sugar maple, Red oak, Red maple	2.5	1.7	1.1	0.6
Black birch, White oak, American beech, Black oak, Pitch pine, Yellow birch, Chestnut oak	2.2	1.5	0.9	0.5
Scarlet oak, Hickory	1.7	1.1	0.7	0.4

1/ These figures may be regarded as fairly accurate for large groups of trees, but not for an individual tree.

Table 10.--Cull factors for trees growing in natural stands, site I

(Percent of total cubic-foot volume, to a 4-inch top)

D.b.h. (inches)	American beech	Black birch	Red maple	Trembling aspen	Chestnut, black, and scarlet oak	Red oak	White ash	Yellow birch	Basswood and sugar maple	E. white pine and white oak	Black cherry	E. hemlock and yellow poplar
SAW-TIMBER STANDS												
4	12	5	8	(1/)	(1/)	4	8	6	4	4	5	1
6	14	8	9	(1/)	(1/)	4	6	7	5	5	4	2
8	16	11	10	(1/)	(1/)	5	6	7	5	5	3	3
10	18	15	11	(1/)	(1/)	6	6	8	6	5	3	3
12	21	19	13	(1/)	(1/)	8	7	8	7	6	4	4
14	24	23	15	(1/)	(1/)	9	7	9	8	7	4	5
16	27	27	18	(1/)	(1/)	11	9	9	9	7	6	7
18	31	31	22	(1/)	(1/)	13	10	10	10	8	8	8
20	35	36	26	(1/)	(1/)	15	12	12	12	10	10	9
22	40	41	31	(1/)	(1/)	17	14	14	14	12	12	11
24	46	47	38	(1/)	(1/)	19	17	16	16	14	14	13
POLE-TIMBER STANDS												
4	6	4	6	13	4	2	9	1	2	3	4	(2/)
6	7	6	7	8	4	3	5	1	3	2	3	--
8	9	8	8	5	5	4	3	2	4	3	2	--
10	10	10	10	6	6	5	3	3	5	3	3	--
SEEDLING-AND-SAPLING STANDS												
4	(2/)	--	3	13	1	--	--	--	--	--	--	--
6	--	--	4	6	2	1	--	--	--	--	--	--
8	--	--	4	2	3	2	--	--	--	--	--	--

1/ Insufficient data. 2/ Negligible.

Table 11.--Cull factors for trees growing in natural stands, site II

(Percent of total cubic-foot volume, to a 4-inch top)

D.b.h. (inches)	Yellow birch	Black birch	Scarlet oak	American beech	Red maple	Trembling aspen	Basswood	Chestnut oak	Sugar maple red oak and E. hemlock	Black oak	White ash	E. white pine pitch pine and hickory	White oak and black cherry
SAW-TIMBER STANDS													
4	(1/)	9	(1/)	12	9	(1/)	6	4	4	5	7	6	4
6	(1/)	13	(1/)	14	9	(1/)	7	5	5	5	7	6	5
8	(1/)	17	(1/)	16	10	(1/)	8	6	5	5	7	7	5
10	(1/)	22	(1/)	19	11	(1/)	10	8	6	6	8	7	5
12	(1/)	27	(1/)	22	13	(1/)	12	10	8	6	8	8	6
14	(1/)	33	(1/)	26	15	(1/)	14	13	10	8	9	8	7
16	(1/)	39	(1/)	30	18	(1/)	17	16	12	10	10	9	8
18	(1/)	45	(1/)	34	22	(1/)	20	20	15	12	12	10	10
20	(1/)	52	(1/)	39	27	(1/)	25	26	18	16	14	11	12
22	(1/)	60	(1/)	44	34	(1/)	31	31	21	20	16	13	14
24	(1/)	70	(1/)	50	46	(1/)	40	37	25	27	19	16	18
POLE-TIMBER STANDS													
4	55	8	15	7	6	17	4	4	2	4	11	4	4
6	57	10	17	8	7	10	4	5	3	4	7	5	3
8	59	12	20	9	8	6	5	6	4	5	4	6	2
10	61	14	23	11	10	7	6	7	6	7	4	8	4
SEEDLING-AND-SAPLING STANDS													
4	30	7	3	1	3	10	(2/)	1	1	1	--	--	--
6	32	8	3	1	4	4	--	2	2	3	--	--	--
8	35	9	4	1	5	4	--	4	3	5	--	--	--

1/ Insufficient data. 2/ Negligible.

Table 12.--Ten-year mortality, site I

(Percent of total number of trees)

SAW-TIMBER STANDS

D.b.h. (inches)	Yellow birch	Trembling aspen	Chestnut oak and scarlet oak	Black birch and yellow poplar	Black cherry	White ash and basswood	Red maple	White oak and hickory	Red oak and black oak	Eastern white pine	E. hemlock American beech and sugar maple
1	35	(1/)	(1/)	73	62	35	18	11	12	12	9
2	28	(1/)	(1/)	47	40	26	14	9	9	9	7
3	23	(1/)	(1/)	31	25	19	10	7	7	6	5
4	18	(1/)	(1/)	19	15	14	6	6	5	5	3
5	15	(1/)	(1/)	11	8	10	3	5	4	4	2
6	12	(1/)	(1/)	6	3	7	2	4	3	3	0.5
7	10	(1/)	(1/)	2	0.5	5	1	3	2	2	--
8	8	(1/)	(1/)	0.5	--	3	0.5	2	1	1	--
9	6	(1/)	(1/)	--	--	1	--	1	1	0.5	--
10	4	(1/)	(1/)	--	--	0.5	--	0.5	0.5	--	--
11	2	(1/)	(1/)	--	--	--	--	--	--	--	--
12	0.5	(1/)	(1/)	--	--	--	--	--	--	--	--
POLE-TIMBER STANDS											
1	68	75	40	37	42	28	17	28	25	10	11
2	51	60	28	22	29	19	12	20	19	8	7
3	37	47	19	13	18	11	8	12	14	6	4
4	26	35	12	7	11	6	5	7	10	4	2
5	18	24	6	3	6	3	3	3	7	5	0.5
6	12	15	3	0.5	3	1	1	0.5	5	2	--
7	7	9	1	--	0.5	0.5	0.5	--	3	1	--
8	4	5	1	--	--	--	--	--	1	0.5	--
9	2	5	0.5	--	--	--	--	--	0.5	--	--
10	0.5	8	--	--	--	--	--	--	--	--	--
SEEDLING-AND-SAPLING STANDS											
1	75	48	55	7	16	20	14	30	27	60	14
2	55	37	20	3	7	7	8	8	11	15	6
3	38	28	5	0.5	0.5	0.5	4	0.5	2	5	1
4	26	22	1	--	--	--	0.5	--	0.5	1	0.5
5	17	17	0.5	--	--	--	--	--	--	0.5	--
6	9	12	--	--	--	--	--	--	--	--	--
7	3	8	--	--	--	--	--	--	--	--	--
8	0.5	5	--	--	--	--	--	--	--	--	--

1/ Insufficient data.

Table 13.--Ten-year mortality, site II

(Percent of total number of trees)

SAW-TIMBER STANDS

D.b.h. (inches)	Yellow poplar and black cherry	Black oak and scarlet oak	Yellow birch	Trembling aspen	Chestnut oak	Red maple	White ash	Eastern white pine	Basswood	Red oak	Black birch	White oak and hickory	E. hemlock American beech and sugar maple
1	90	73	57	(1/)	26	45	51	51	43	25	(1/)	20	12
2	60	52	42	(1/)	20	36	40	37	34	20	(1/)	17	9
3	44	37	33	(1/)	15	29	30	26	26	16	(1/)	15	7
4	30	25	26	(1/)	11	23	24	18	20	13	(1/)	13	5
5	20	16	20	(1/)	8	18	17	12	15	10	(1/)	10	3
6	11	10	15	(1/)	5	14	13	7	11	8	(1/)	7	2
7	6	5	12	(1/)	4	10	6	4	8	6	(1/)	5	0.5
8	3	3	9	(1/)	3	7	4	2	5	4	(1/)	3	--
9	0.5	2	6	(1/)	2	5	2	1	2	2	(1/)	2	--
10	--	1	4	(1/)	1	3	1	0.5	0.5	1	(1/)	1	--
11	--	0.5	2	(1/)	0.5	1	0.5	--	--	0.5	(1/)	0.5	--
12	--	--	0.5	(1/)	--	0.5	--	--	--	--	(1/)	--	--
POLE-TIMBER STANDS													
1	75	70	72	60	54	18	40	36	22	28	35	30	13
2	45	48	55	46	37	12	27	25	13	22	23	21	9
3	28	34	42	34	25	8	17	16	6	17	14	14	6
4	15	22	31	25	17	5	10	10	2	11	8	8	4
5	9	13	22	18	10	3	5	5	1	8	3	5	2
6	4	7	16	15	5	1	2	3	0.5	6	0.5	4	1
7	1	3	11	17	3	0.5	1	1	--	4	--	3	0.5
8	0.5	1	6	20	1	--	0.5	0.5	--	2	--	2	--
9	--	0.5	2	24	0.5	--	--	--	--	1	--	1	--
10	--	--	0.5	30	--	--	--	--	--	0.5	--	0.5	--
SEEDLING-AND-SAPLING STANDS													
1	48	65	85	40	66	15	35	25	16	34	20	32	15
2	25	27	60	30	25	9	15	12	9	16	7	10	6
3	13	10	44	21	6	4	5	5	4	7	1	2	3
4	6	5	30	15	1	1	0.5	2	0.5	3	0.5	0.5	1
5	2	1	20	10	0.5	0.5	--	1	--	1	--	--	0.5
6	0.5	0.5	11	8	--	--	--	0.5	--	0.5	--	--	--
7	--	--	5	8	--	--	--	--	--	--	--	--	--
8	--	--	1	9	--	--	--	--	--	--	--	--	--

1/ Insufficient data.

Table 14.--Average maturity sizes and ages[1/]

Species	D.b.h. at which average 10-year growth in cubic feet starts to decline	D.b.h. at which cull exceeds 10 percent of total cubic-foot volume	Relative stumpage value	Approximate d.b.h. at which trees should be cut to get best returns	Years to grow to cutting size	
					In unmanaged stands	In managed stands
	Inches	Inches		Inches		
SITE I						
Eastern white pine	24+	21	High	26	135	110
Eastern hemlock	24+	21	Low	22	120	100
Red oak	18	19	Moderate	20	95	85
White oak	24+	19	High	24	145	110
Sugar maple	24	18	High	22	125	105
Red maple	16	9	Low	14	90	70
Hickory	18	19	Moderate	20	125	115
American beech	16	9	Low	14	110	85
Yellow birch	14	16	High	18	115	100
Black birch	16	9	Moderate	14	85	75
Yellow poplar	18	21	High	24	95	90
White ash	18+	19	High	22	130	105
Black cherry	16	21	Very high	20	100	90
Basswood	22	19	High	22	120	110
Trembling aspen	10	14	Low	12	60	55
SITE II						
Eastern white pine	22	18	High	22	130	115
Eastern hemlock	14	14	Low	14	80	70
Red oak	18	18	Moderate	18	115	100
White oak	24+	19	High	20	155	125
Sugar maple	18	14	High	18	135	105
Red maple	16	9	Low	12	95	65
Hickory	12	13	Moderate	14	150	120
American beech	16	9	Low	12	105	80
Yellow birch[2/]	--	--	--	--	--	--
Black birch	14	5	Moderate	12	80	65
White ash	18+	18	High	18	130	100
Black cherry	14+	20	Very high	18	115	85
Basswood	18+	10	High	16	115	75
Trembling aspen	8	12	Low	10	60	55
Black oak	16	19	Moderate	18	115	100
Chestnut oak	20	12	Moderate	16	110	85

1/ For use in the Anthracite Region of Pennsylvania only. 2/ Poor risk on site II.